DESIGN AND ANALYSIS OF GLASS FIBER REINFORCED PLASTIC ELECTRIC POLE FOR POWER TRANSMISSION

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Abstract

Engineers are increasingly tasked with designing and operating structures that incorporate the philosophy of resiliency across a variety of critical infrastructure sectors. Electric distribution and transmission systems are examples of the critical infrastructure sectors. The majority of existing electrical poles supporting electric distribution systems in the United States are made out of wood.

It is estimated that up to 3.6 million existing electric wood poles have to be replaced every year. One of the primary hardening strategies is upgrading wooden electric poles and supporting structures with stronger materials that withstand hurricane - force winds. In this thesis the electrical pole modeling in CREO parametric software with different pole thicknesses (4mm, 10mm & 15mm) and analysis in ANSYS software with different materials (cast iron, concrete & glass fiber reinforced plastic).

In this thesis the static analysis is to determine the deformation, stress and strain and fatigue analysis is to determine the safety factor.

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IDOAJ-003-0502-076
Year of publication: 2018
Review Type: peer reviewed
Volume: V, Issue: II

Citation: K Sai Sudheer, Research Scholar "The Performance And Emission Characteristics of A Diesel Engine Operated on Diesel Fuel And Palm Biodiesel Blends" Advanced Research Journals of Science and Technology (ARJST) 5.2(2018): 448-455.

INTRODUCTION TO ELECTRICAL POLE

An electric pole is a column or post used to support overhead power lines and various other public utilities, such as cable, fibre optic cable, and related equipment such as transformers and street lights. It can be referred to as a transmission pole, telephone pole, telecommunication pole, power pole, hydro pole, telegraph pole, or telegraph post, depending on its application. A stobie pole is a multi-purpose pole made of two steel joists held apart by a slab of concrete in the middle, generally found in South Australia.

Electrical wires and cables are routed overhead on utility poles as an inexpensive way to keep them insulated from the ground and out of the way of people and vehicles. Utility poles can be made of wood, metal, concrete, or composites like fiberglass. They are used for two
different types of power lines; subtransmission lines which carry higher voltage power between substations, and distribution lines which distribute lower voltage power to customers.

Electric poles were first used in the mid-19th century with telegraph systems, starting with Samuel Morse who attempted to bury a line between Baltimore and Washington, D.C., but moved it aboveground when this system proved faulty. Today, underground distribution lines are increasingly used as an alternative to utility poles in residential neighborhoods, due to poles' perceived ugliness.

**Communication cables**

The communications cables are attached below the electric power lines, in a vertical space along the pole designated the communications space. The communications space is separated from the lowest electrical conductor by the communication worker safety zone, which provides room for workers to maneuver safely while servicing the communication cables, avoiding contact with the power lines.

The most common communication cables found on utility poles are copper or fibre optic cable (FOC) for telephone lines and coaxial cable for cable television (CATV). Coaxial or optical fibre cables linking computer networks are also increasingly found on poles in urban areas. The cable linking the telephone exchange to local customers is a thick cable lashed to a thin supporting cable, containing hundreds of twisted pair subscriber lines. Each twisted pair line provides a single telephone circuit or local loop to a customer. There may also be fibre optic cables interconnecting telephone exchanges. Like electrical distribution lines, communication cables connect to service drops when used to provide local service to customers.

**Pole attachment hardware**

The primary purpose of pole attachment hardware is to secure the cable and associated aerial plant facilities to poles and to help facilitate necessary plant rearrangements.

An aerial plant network requires high-quality reliable hardware to Structurally support the distribution cable plant. Provide directional guying to accommodate lateral stresses created on the pole by pole line configurations and pole loading configuration. Provide the physical support and protection for drop cable plant from the pole to the customer premises. Transition cable plant from the aerial network to underground and buried plant. Provide the means for safe and effective grounding, bonding, and isolation connections for the metallic and dielectric components of the network.

Functional performance requirements common to pole line hardware for utility poles made of wood, steel, concrete, or Fiber-Reinforced Composite (FRC) materials are contained in Telcordia GR-3174, Generic Requirements for Hardware Attachments for Utility Poles.

**Wood poles**

The traditional wood pole material provides great flexibility during placement of hardware and cable apparatus. Holes are easily drilled to fit the exact hardware needs and requirements. In addition, fasteners such as lags and screws are easily applied to wood structures to support outside plant (OSP) apparatus.

**Dead-end poles**

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**Example of dead-end riser poles**

The poles at the end of a straight section of utility line where the line ends or angles off in another direction are called dead-end poles in the United States. Elsewhere they may be referred to as anchor or termination poles. These must carry the lateral tension of the long straight sections of wire. They are usually made with heavier construction. The power lines are attached to the pole by horizontal strain insulators, either placed on crossarms (which are either doubled, tripled, or replaced with a steel crossarm, to provide more resistance to the tension forces) or attached directly to the pole itself.

Dead-end and other poles that support lateral loads have guy-wires to support them. The guys always have strain insulators inserted in their length to prevent any high voltages caused by electrical faults from reaching the lower portion of the cable that is accessible by the public. In populated areas, guy wires are often encased in a yellow plastic or wood tube reflector attached to their lower end, so that they can be seen more easily, reducing the chance of people and animals walking into them or vehicles crashing into them.

Another means of providing support for lateral loads is a push brace pole, a second shorter pole that is attached to the side of the first and runs at an angle to the ground. If there is no space for a lateral support, a stronger pole, e.g. a construction of concrete or iron, is used.

**Environmental impact**

Utility pole Steps of Antti by Antti Nurmesniemi in Helsinki, Finland. [icon]

This section needs expansion. You can help by adding to it. (August 2012) White storks (Ciconia ciconia) in their nest on a utility pole in Romania Utility poles are used by birds for nesting and to rest on. Utility poles and related structures are regarded by some to be a form of visual pollution. Many lines are placed underground for this reason, in places of high population density or scenic beauty that justify the expense. Architects design some pylons to be pretty, thus avoiding visual pollution.
LITERATURE REVIEW

Dai Gil Lee et. al., Author explained that Substituting composite structures for conventional metallic structures have many advantages because of higher specific stiffness and higher specific strength of composite materials. In this work, one-piece automotive hybrid aluminum/composite drive shaft was developed with a new manufacturing method, in which a carbon fiber epoxy composite layer was co-cured on the inner surface of an aluminum tube rather than wrapping on the outer surface to prevent the composite layer from being damaged by external impact and absorption of moisture. From experimental results, it was found that the developed one-piece automotive hybrid aluminum/composite drive shaft had 75% mass reduction, 160% increase in torque capability compared with a conventional two-piece steel drive shaft. It also had 9390 rpm of natural frequency which was higher than the design specification of 9200 rpm. M.A. Badie , In this paper examined the effect of fiber orientation angles and stacking sequence on the torsional stiffness, natural frequency, buckling strength, fatigue life and failure modes of composite tubes. Finite element analysis. (FEA) has been used to predict the fatigue life of composite drive shaft (CDS) using linear dynamic analysis for different stacking sequence. FEA results showed that the natural frequency increases with decreasing fiber orientation angles. Robert S. Salzare et. al., this paper demonstrates a logical step in the application of fiber-reinforced composites is to take advantage of their light-weight/high-strength potential and replace traditional monolithic shaft designs with composite materials. In the case of aircraft engine shafts where the high-temperature environment excludes the use of most traditional materials, a high-strength titanium alloy is recommended. The feasibility of using lighter weight/stronger composite shafts, as well as the complexity of the design problem, along with the careful consideration.

INTRODUCTION TO CAD

Computer-aided design (CAD) is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. The term CADD (for Computer Aided Design and Drafting) is also used.

INTRODUCTION TO CREO

CREO is a one of the world’s leading high-end CAD/CAM/CAE software packages.

CREO (Computer Aided Three dimensional Interactive Application) is a multi-platform PLM/CAD/CAM/CAE commercial software suite developed by Dassault Systems and marketed world-wide by IBM. CREO is written in the C++ programming language. CREO provides open development architecture through the use of interfaces, which can be used to customize or develop applications. The application programming interfaces supported Visual Basic and C++ programming languages. Commonly referred to as 3D Product Lifecycle.

Management (PLM) software suite, CREO supports multiple stages of product development. The stages range from conceptualization, through design (CAD) and manufacturing (CAM), until analysis (CAE). Each workbench of CREO V5 refers to each stage of product development for different products. CREO V5 features a parametric solid/surface-based package which uses NURBS as the core surface representation and has several workbenches that provide KBE (Knowledge Based Engineering) support.

Models in CREO

The above image shows part design of pole

INTRODUCTION TO FEA

Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variational calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Top established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures".
Types of Engineering Analysis

Structural analysis consists of linear and non-linear models. Linear models use simple parameters and assume that the material is not plastically deformed. Non-linear models consist of stressing the material past its elastic capabilities. The stresses in the material then vary with the amount of deformation as in.

Vibrational analysis is used to test a material against random vibrations, shock, and impact. Each of these incidences may act on the natural vibrational frequency of the material which, in turn, may cause resonance and subsequent failure.

Heat Transfer analysis models the conductivity or thermal fluid dynamics of the material or structure. This may consist of a steady-state or transient transfer. Steady-state transfer refers to constant thermo properties in the material that yield linear heat diffusion.

INTRODUCTION TO ANSYS

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

ANSYS is the standard FEA teaching tool within the Mechanical Engineering Department at many colleges. ANSYS is also used in Civil and Electrical Engineering, as well as the Physics and Chemistry departments.

ANSYS provides a cost-effective way to explore the performance of products or processes in a virtual environment. This type of product development is termed virtual prototyping. With virtual prototyping techniques, users can iterate various scenarios to optimize the product long before the manufacturing is started. This enables a reduction in the level of risk, and in the cost of ineffective designs. The multifaceted nature of ANSYS also provides a means to ensure that users are able to see the effect of a design on the whole behavior of the product, be it electromagnetic, thermal, mechanical etc.

Define Material Properties Now that the part exists, define a library of the necessary materials that compose the object (or project) being modeled. This includes thermal and mechanical properties.

STATIC ANALYSIS OF ELECTRICAL POLE

Thickness of electrical pole- 4mm, 10mm & 15mm
Materials = cast iron, concrete & glass fiber reinforced plastic
Material - cast iron

material properties:
Density = 7.81g/cc
Young’s modulus = 240GPa
Poisson’s ratio = 0.370

Material – concrete
Density = 6.50g/cc
Young’s modulus = 30GPa
Poisson’s ratio = 0.3

Material – glass fiber reinforced plastic
Density = 2.58g/cc
Young’s modulus = 72.3GPa
Poisson’s ratio = 0.2
CASE: 1 THICKNES OF ELECTRICAL POLE 4mm
Material: cast iron

Deformation

Material: concrete

Deformation

Stress

Strain

Safety factor
CASE: 2 THICKNES OF ELECTRICAL POLE 10mm
Material: cast iron
Deformation

Material- glass fiber reinforced plastic
Deformation

Stress

Strain

Safety factor
CASE: 3 THICKNES OF ELECTRICAL POLE 15mm
Material- cast iron
Deformation

RESULT TABLE

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<thead>
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<th>Model</th>
<th>Material</th>
<th>Deformation (mm)</th>
<th>Stress (MPa)</th>
<th>Strain</th>
<th>Safety factor</th>
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CONCLUSION

In this thesis the electrical pole modeling in CREO parametric software with different pole thicknesses (4mm, 10mm & 15mm) and analysis in ANSYS software with different materials (cast iron, concrete & glass fiber reinforced plastic).

In this thesis the static analysis is to determine the deformation, stress and strain and fatigue analysis is to determine the safety factor.

By observing the static analysis results the stress values are increases by decreasing the electrical pole thickness. The stress values are less for glass fiber reinforced plastic material.

So it can be concluded the glass fiber reinforced plastic material is better material for electric pole and 15mm thickness model is better model.

REFERENCES


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